Ontario
Ministry of Transportation
Ministère des Transports

MI-132

EVALUATION OF HOT MIX PAVEMENT MODIFIED WITH CELLULOSE FIBRES

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

EVALUATION OF HOT MIX PAVEMENT MODIFIED WITH CELULOSE FIBRES

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FEBRUARY 1989

IBSN 0-7729-5359-7

SUMMARY

In 1988 the Ontario Ministry of Transportation conducted both a laboratory evaluation and a field trial of hot-mixed asphaltic concrete modified by the inclusion of cellulose fibres.

Cellulose fibres were developed in Europe as a substitute for asbestos fibres in bituminous systems. It is claimed that cellulose fibres will make the hot-mix resistant to cracking and rutting due to three-dimensional reinforcement.

This report presents the results of the laboratory analysis and observations during construction of a field trial.

The cellulose fibres were found to have little effect on the Marshall properties of a hot-mixed pavement.

The cellulose fibres had little effect on production, transportation, placing and compaction of the hot-mix except for a problem of mix pick-up on the tires of the pneumatic tire roller.

The Bituminous Section will continue to monitor the field trial to determine the long term effectiveness of a cellulose modified mix.

RÉSUMÉ

En 1988, le ministère des Transports de l'Ontario a effectué, tant en laboratoire que dans des conditions réelles, une évaluation du béton bitumineux préparé à chaud, modifié par inclusion de fibres cellulosiques.

Les fibres cellulosiques ont été mises au point en Europe pour remplacer les fibres d'amiante des revêtements bitumineux. Formant un renfort tridimensionnel, les fibres cellulosiques doivent rendre le mélange préparé à chaud résistant à la fissuration et à la formation d'ornières.

Ce rapport présente les résultats de l'analyse en laboratoire, ainsi que les observations relevées lors de la réalisation d'un essai dans des conditions réelles.

L'essai a révélé que les fibres cellulosiques n'ont que peu d'effet sur les propriétés Marshall des revêtements préparés à chaud.

Les fibres cellulosiques n'ont que peu d'effet sur les opérations de production, de transport, de mise en place et de compactage du mélange à chaud; le seul problème a été soulevé par l'adhérence du mélange sur les pneus des rouleaux compresseurs à pneus.

La Section des revêtements bitumineux va poursuivre son évaluation de l'étude sur le terrain, afin d'établir l'efficacité à long terme des revêtements additionnés de cellulose.

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1 INTRODUCTION

In 1987 De Jong Prochem Inc. of Don Mills Ontario, suppliers of ARBOCEL ZZ 8/1, produced by J. Rettenmaier & Son in the Federal Republic of Germany, approached the Ministry to construct a trial section of hot mix paving incorporating their product.

ARBOCEL ZZ 8/1 reinforced hot mix, it was claimed, would improve cold temperature flexibility, resist cracking and rutting due to the three dimensional reinforcement it gives.

ARBOCEL ZZ 8/1 was specially developed at the end of the 60's as an asbestos substitute for bituminous systems. The physical properties are:

Cellulose Content	75-80%
Maximum Length	about 5.0 mm
Average Length	about 1.1 mm
Average Diameter	about 0.045 mm
Mass Density	.025 to .030
pH	7.5 ±1
Physiologically Harmless	

The fibres are added at the rate of 3.0 kg/t of dense graded hot mix.

The Ministry agreed to conduct laboratory analysis of mixes incorporating ARBOCEL ZZ 8/1 fibres and subsequently a field trial.

2 LABORATORY MIX TRIAL

A standard laboratory HL-3 mix of known borderline stability was modified by the inclusion of two different sources of cellulose fibres. ARBOCEL ZZ 8/1 fibres and a domestic product, Hartford Fibre Ltd. type ARS random cut were used. The three mixes (control, ARBOCEL ZZ 8/1 and Hartford) were prepared in triplicate at three asphalt cement contents. The fibre content was set at 0.3% of the aggregate.

The aggregates and the fibres were pre-mixed by hand for 15 seconds and placed in a 170°C oven overnight. The next day, the mixture was mechanically dry mixed for 15 seconds before addition of asphalt cement and a wet mixing cycle of 45 seconds. Both fibres dispersed easily in the mix. The mixes consisted of:

43% Coarse Aggregate (Canada Crushed),
57% Fine Aggregate (Cloverdale sand), producing a total grading of 45% coarse aggregate.

It was expected that the fibres would create a demand for additional asphalt cement in the mix. In fact, all three mixes have the same asphalt cement content (6.1%) at 3% voids. The Voids, Flow and BRD curves are very close for all three mixes but the Stability curves vary a little with the control mix falling between the two fibre mixes. Overall, modification of the mix with either fibre had little impact on Marshall values. Figure 1 contains the Marshall values for the three mixes.

3 FIELD TRIAL

3.1 Criteria

1. The trial to contain approximately 50 t of fibre modified mix;

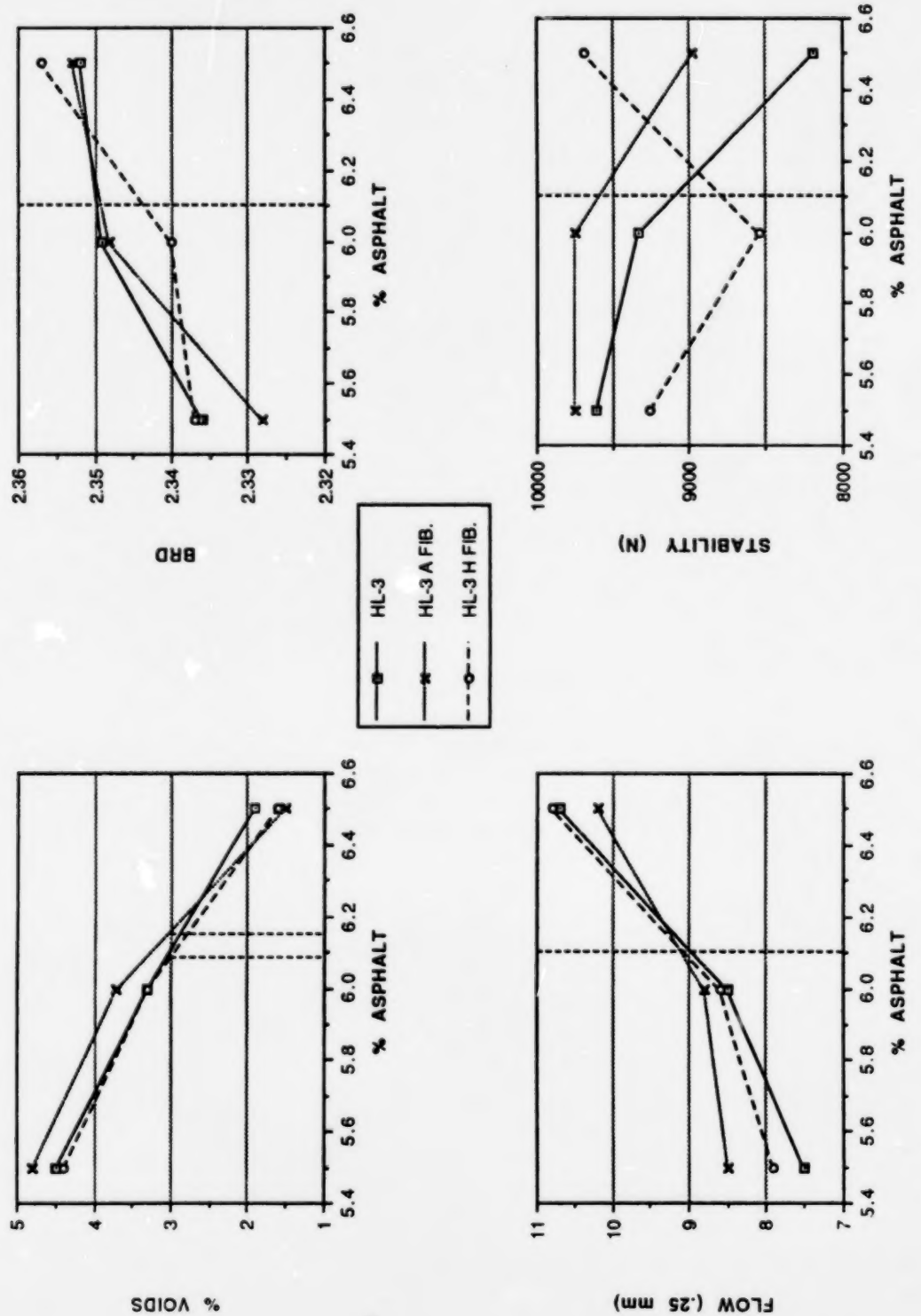
2. The trial to be placed adjacent to the same mix without fibres as a control for evaluation purposes;

3. The trial to be constructed on a heavy traffic volume highway;

4. The trial to be constructed over a badly cracked existing pavement where reflection cracks would be expected to occur.

This worst case scenario is intended to provide a severe environment for a meaningful evaluation.

FIG: 1 MARSHALL VALUES OF TRIAL MIXES



3.2 Location

A section of Hwy. 403 westbound in Hamilton, between the west junction of Hwy. 6 and Hwy. 2 interchanges and just west of the Desjardin Canal bridge was selected for the trial. As part of Burlington District's hot mix patching contract CRC 04-88-16, a 400 m long patch was to be constructed at this location The west-bound lanes at this location are three lanes wide with a partial paved shoulder. All three lanes and shoulder were to be patched.

The 1987 traffic volume for Hwy. 403 in this area was 56,100 AADT.

The fibre modified mix was placed part-way through the patch on the right lane and shoulder so that there would be control mix on either end of it and beside it. A key map is presented in the Appendix.

3.3 Pavement Condition

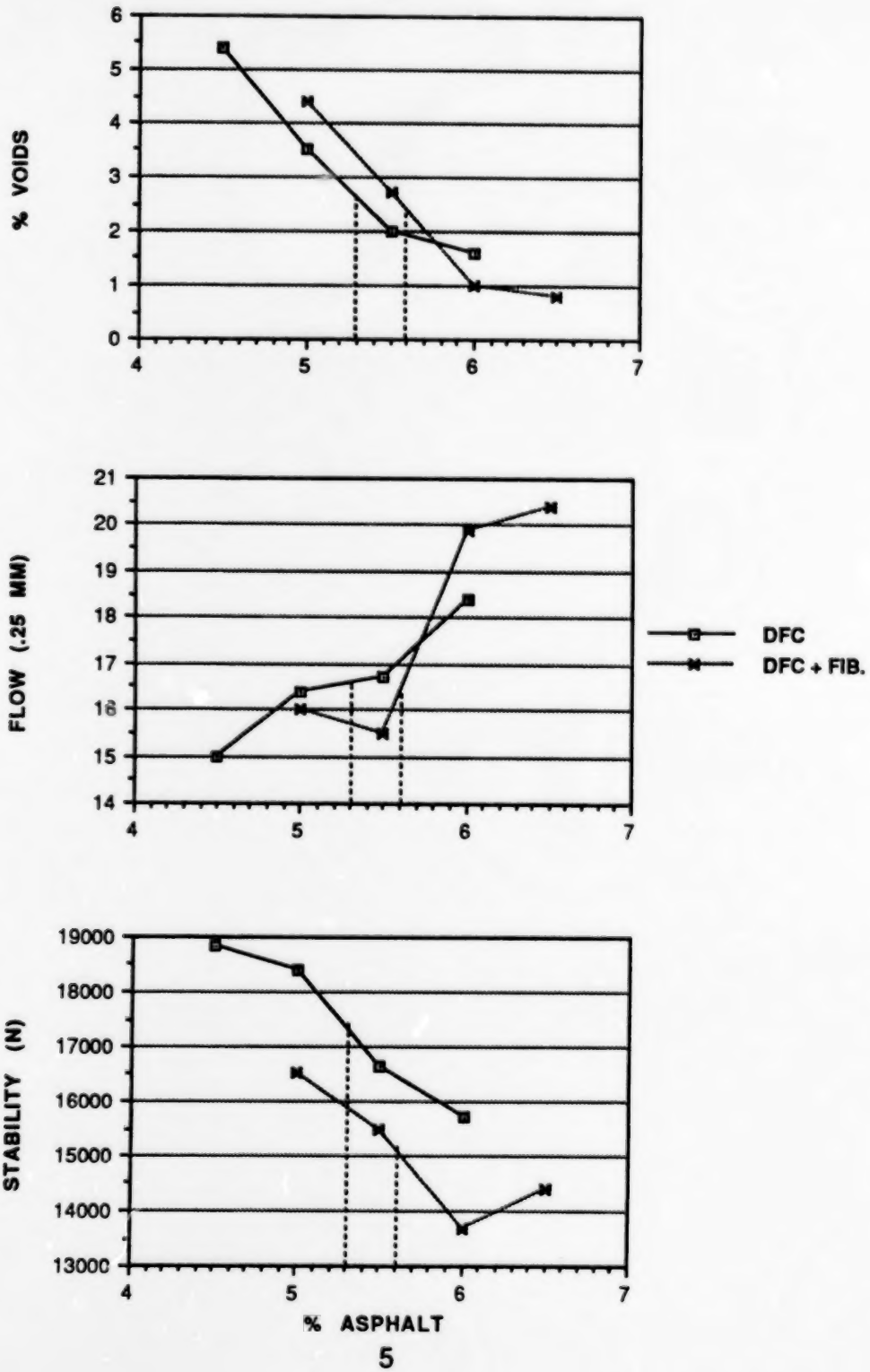
All lanes were extensively cracked with much fatigue cracking in the right and centre lanes. The original condition crack survey is contained in the Appendix.

3.4 Mix Design

The DFC patching mix design, (control) consisted of:
49% coarse aggregate (Dofasco steel slag),
51% fine aggregate (Dofasco steel slag screenings),
5.3%, 85-100 grade asphalt cement (by weight of aggregate).

This mix was modified for the trial by the addition of 0.3% ARBOCEL ZZ 8/1 by weight of aggregate (3.0 kg/t) and an increase in the asphalt content from 5.30 to 5.60 %. The extra asphalt cement was required to coat the fibres. The Marshall values for both mixes are presented in Figure 2.

FIG: 2 MARSHALL VALUES OF PATCHING MIXES



3.5 Mixing

The mix was produced at Red-D-Mix Concrete, Asphalt Division, Hamilton West batch plant, for Permanent Paving Company, Hamilton, the prime contractor, on 88 10 16. The 1.0 kg polyethylene bags of fibres were stacked on the mixer platform and three bags per tonne of mix were deposited into the pugmill through an open inspection plate (the polyethylene bags melt in the mix). The ARBOCEL ZZ 8/1 mix was batched between 140 and 150°C. The dry mixing cycle was extended to 30 s and the wet mixing cycle remained the same for both mixes at 25 s. No problems were encountered producing the ARBOCEL ZZ 8/1 mix at the hot mix plant.

3.6 Mix Placing

The right lane and partial shoulder was paved first in a single operation starting with the control mix and then switching to the ARBOCEL ZZ 8/1 mix after 130 m. Two truckloads of ARBOCEL ZZ 8/1 mix were then placed covering 75 m and then control mix to the end of the patch. Although being placed at 40 mm or better, the control mix came out from under the screed with a torn, open texture and a more stoney appearance down the centre of the mat. When the paving operation switched to the ARBOCEL ZZ 8/1 mix, the mat was less torn but still coarser down the centre. The ARBOCEL ZZ 8/1 mix appeared dryer than the control mix behind the paver.

The contractor's personnel performing handwork commented that the ARBOCEL ZZ 8/1 mix was easier to shovel and rake than the control mix.

3.7 Compaction

Rolling was carried out with a Dynapac CC-42A breakdown roller, operated in vibratory mode, followed by a Bomag 12 R pneumatic finishing roller. The pneumatic roller had slight to moderate pick-up on the ARBOCEL ZZ 8/1 mix even though the tires were already warmed up from the first 130 m of control mix. A light application of diesel fuel on the tires minimized the pick-up problem. The compaction equipment did not close up the open, torn texture on the control mat but the fibre modified mix did tighten up a little better. After compaction the ARBOCEL ZZ 8/1 mix appeared as rich as the control mix.

4 TESTING

4.1 Laboratory Testing

Six plate samples of the ARBOCEL ZZ 8/1 modified mix were obtained and tested in the Regional mobile laboratory to determine asphalt cement content, gradation of the extracted aggregates and Marshall values. Table I summarizes the test results.

The untested balance of the plate samples were shipped in two bags to the Downsview central laboratory for replicate testing. Table 2 contains the results of the Downsview testing.

Two months after construction, four sets of five cores were obtained from the trial site. Sets #1 and #4 were cut from the control mix either end of the ARBOCEL ZZ 8/1 trial area and sets #2 and #3 from within it. These cores were tested in the Downsview laboratory for asphalt cement content, gradation of the extracted aggregates and Marshall values. The test results are presented in tables 3 and 4.

TABLE 1: ARBOCEL ZZ 8/1 PLATE SAMPLE TEST RESULTS FROM REGIONAL MOBILE LABORATORY

	% A.C.	% +4.75	% FIB.	VOIDS	FLOW	STABILITY
TARGET	5.60	51.1	0.30	2.5	16.3	15160
SAMPLE						
1	4.94	58.0	0.21	3.0	19.4	15526
2	5.34	55.3	0.81	1.3	19.3	16580
3	5.45	55.9	0.41	0.3	18.2	14947
4	5.15	54.8	0.50	0.7	20.3	17166
5	4.83	61.0	0.59	1.0	16.4	16396
6	5.26	58.2	0.76	1.8	18.9	16912
MEAN	5.16	57.2	0.55	1.35	18.8	16254

TABLE 2: ARBOCEL ZZ 8/1 PLATE SAMPLE TEST RESULTS FROM DOWNSVIEW CENTRAL LABORATORY

	% A.C.	% +4.75	% FIB.	VOIDS	FLOW	STABILITY
TARGET	5.60	51.1	0.30	2.5	16.3	15160
SAMPLE						
1	5.70	47.4	0.30	2.4	19.7	17134
2	5.60	49.9	0.20	2.1	21.8	17869
MEAN	5.65	48.6	0.25	2.25	20.8	17502

TABLE 3: ARBOCEL ZZ 8/1 CORE SAMPLE TEST RESULTS FROM DOWNSVIEW CENTRAL LABORATORY

	% A.C.	% +4.75	% FIB.	VOIDS	FLOW	STABILITY
TARGET	5.60	51.1	0.30	2.5	16.3	15160
Core						
2	5.36	50.4	0.33	2.2	21.4	20217
2a	5.10	50.4	0.15			
2b	5.26	49.9	0.20			
3	5.43	49.6	0.29	2.8	18.4	19608
3a	5.28	50.9	0.40			
3b	5.02	57.7	0.25			
MEAN	5.24	51.5	0.27	2.5	19.9	19912

TABLE 4: CONTROL CORE SAMPLE TEST RESULTS FROM DOWNSVIEW CENTRAL LABORATORY

	% A.C.	% +4.75	% FIB.	VOIDS	FLOW	STABILITY
TARGET	5.30	51.1	0.00	2.5	16.6	17300
Core						
1	5.15	46.4	0.00	3.3	16.8	19102
1a	5.01	51.1	0.00			
1b	5.34	42.6	0.00			
4	5.34	46.4	0.00	2.5	16.1	17801
4a	5.41	46.9	0.00			
MEAN	5.25	46.7	0.00	2.9	16.5	18452

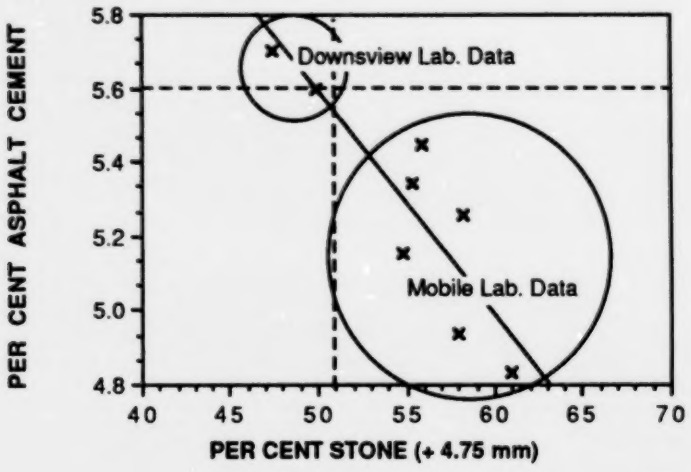
The asphalt cement and stone content determinations, from the two laboratories on the plate samples, appear to represent different materials even though the test portions were derived from the same samples. An analysis of the asphalt cement content vs the stone content determinations indicates that the Regional mobile laboratory consistently tested a coarser fraction of the sample than did the Downsview laboratory. With the test results of both laboratories plotted on a scatter chart, along with the linear regression best-fit line, it can be seen that there is a very strong relationship (R^2 = 0.78) between the stone and asphalt cement content determinations. This strong relationship confirms that the samples were segregated in the process of reducing them to test portion size. The scatter chart is presented in Figure 3 along with the target values indicated by the dashed lines.

The average asphalt cement content of the fibre mix as determined by both laboratories on the plate samples is 5.28% and 5.24% for the core samples. The control mix (core samples) was determined to contain 5.25% asphalt cement. Virtually the same asphalt cement content for both mixes. It would appear that the contractor forgot to add the extra 0.3% asphalt cement to the fibre mix.

The fibre contents are difficult to determine because the fibres are so fine and light they are prone to being lost in washing and sieving.

Contrary to the mix design data, the ARBOCEL ZZ 8/1 modified mix has slightly higher flow and stability than the control mix as determined from the core samples.

FIG. 3: ASPHALT CEMENT CONTENT vs STONE CONTENT



$R^2 = 0.78$

5 FIELD EVALUATIONS

5.1 NOVEMBER 23, 1988

Six weeks after construction, the ARBOCEL ZZ 8/1 mix looked tighter than the control mix. A few small areas of slight to medium segregation were observable in the fibre-modified patch compared to many small segregated areas in the control areas. Overall, both mixes were stony up the centre of the mat but less so in the fibre mix. No cracks were evident in any area of the patch.

5.2 FEBRUARY 16, 1989

During this mid-winter evaluation, one full-lane transverse crack was observed in the ARBOCEL ZZ 8/1 mix and two in the control mix in the adjacent lane to the left. No cracks were observed in the control mix preceding the ARBOCEL ZZ 8/1 mix area but there were seven three-lane and three two-lane transverse cracks and two short meandering longitudinal cracks in the control mix beyond.

6 COSTS

De Jong Prochem Inc., supplied the ARBOCEL ZZ 8/1 for the trial at no cost to the Ministry. Permanent Paving Company / Red-D-Mix, charged $26.11 for the extra asphalt cement to produce the 43.9 tonnes of fibre modified mix.

Assuming the need for an extra 0.3% asphalt cement the estimated extra cost to produce a tonne of ARBOCEL ZZ 8/1 modified mix would be $0.59 for additional asphalt cement (198.23/t) and $7.50 for the fibres ($2.50/kg), resulting in a total of $8.09 (1988 Prices). This figure does not include any premium that a contractor may charge to produce such a mix.

7 DISCUSSION

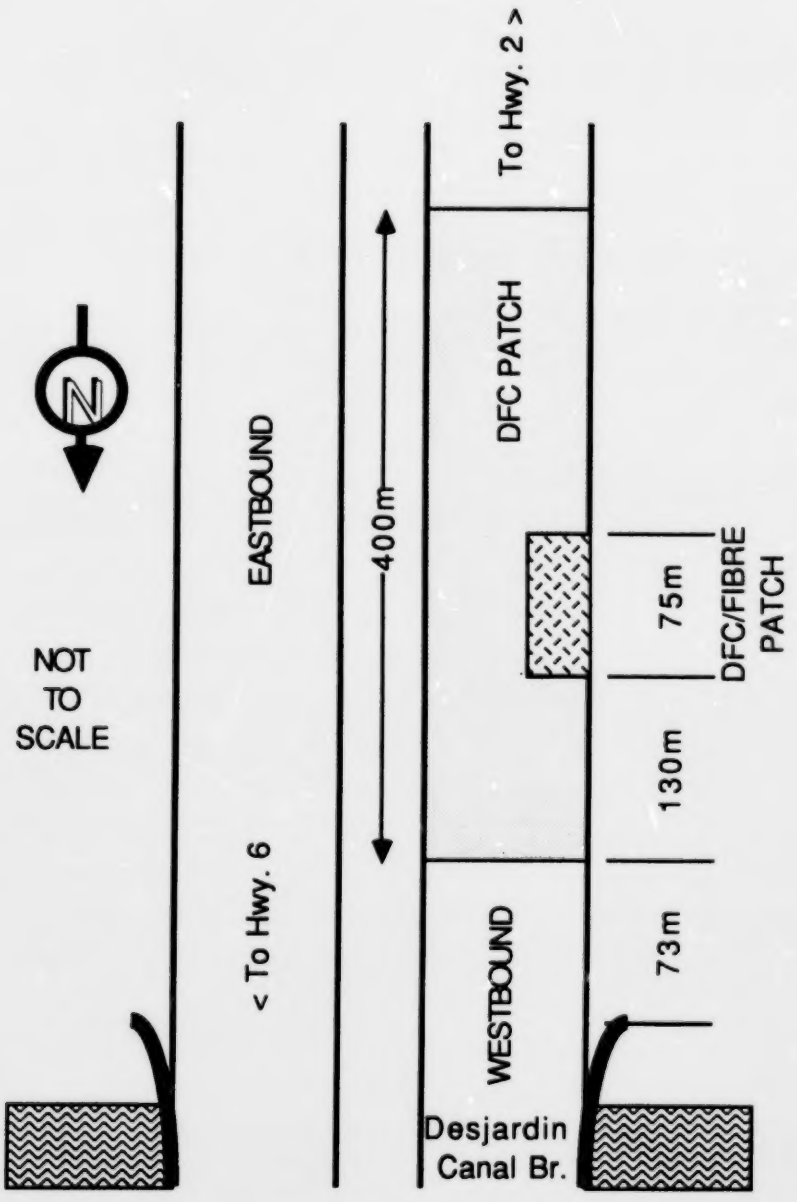
Both the ARBOCEL ZZ 8/1 and Hartford ARS cellulose fibres were found to blend easily into the hot-mix in the laboratory and have little affect on Marshall values. The ARBOCEL ZZ 8/1 fibres were also found to blend easily into the hot-mix in a pug-mill type hot-mix plant. The ARBOCEL ZZ 8/1 fibres were found to require an extra 0.3% asphalt cement in a DFC mix. Neither fibre required any additional asphalt cement in the HL-3 mix design produced.

The only problem in mixing, placing and compacting the ARBOCEL ZZ 8/1 modified DFC mix was with pick-up on the tires of the pneumatic tire roller.

The Bituminous Section will continue to monitor the field trial to determine the long term benefits of ARBOCEL ZZ 8/1 fibres in a mix.

8 APPENDIX

KEY MAP



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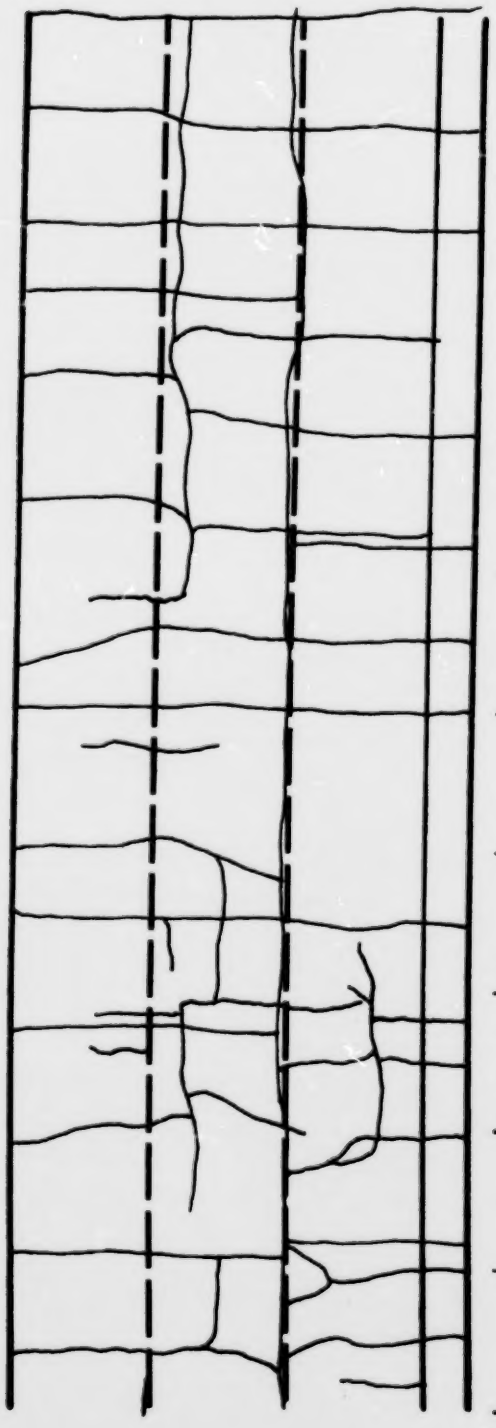

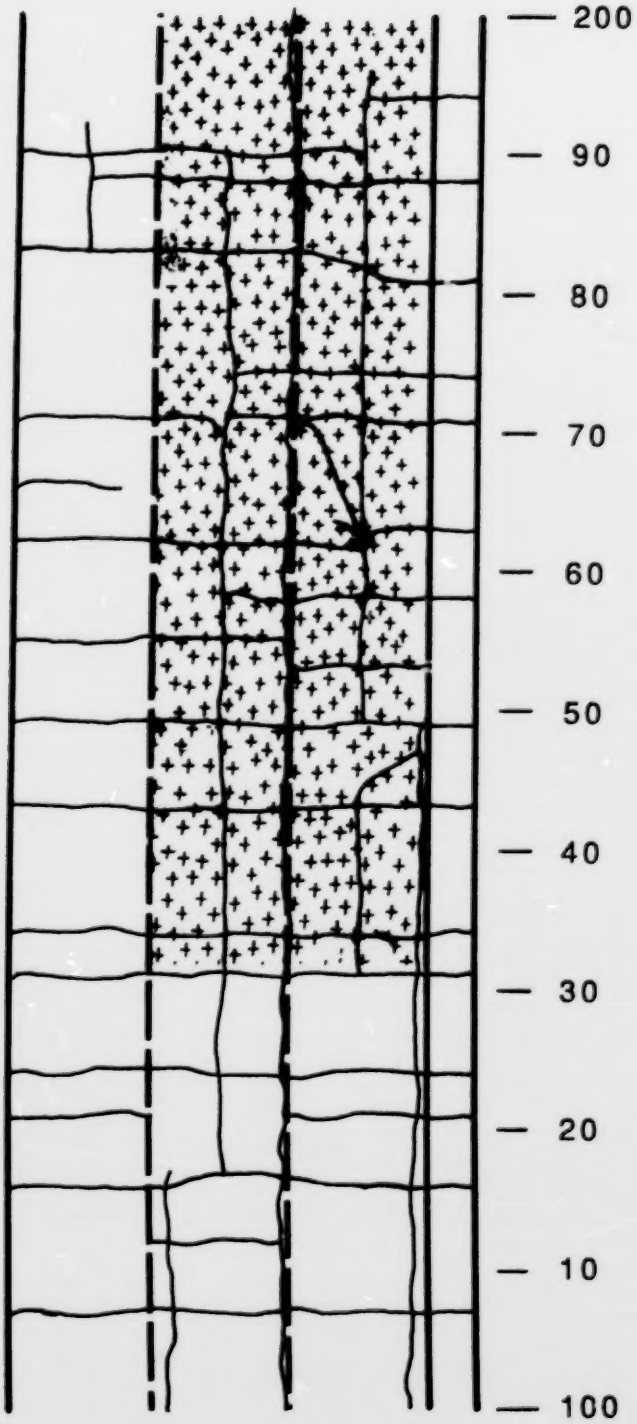
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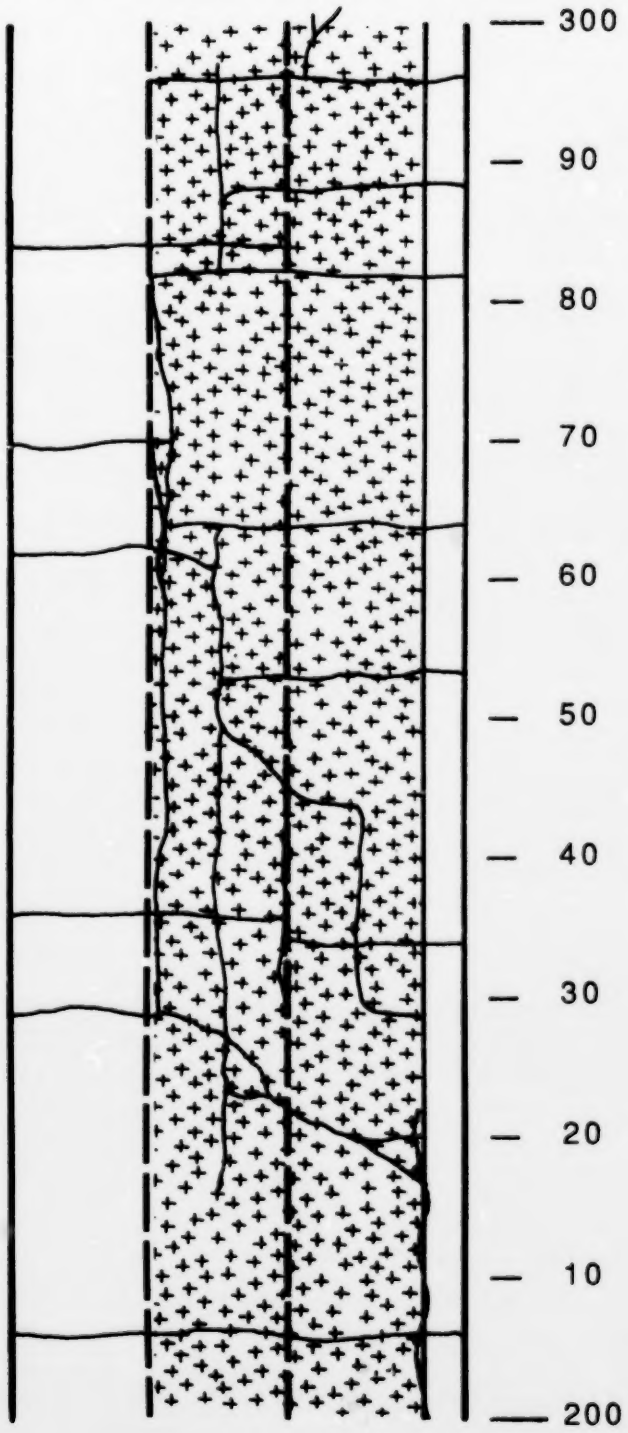
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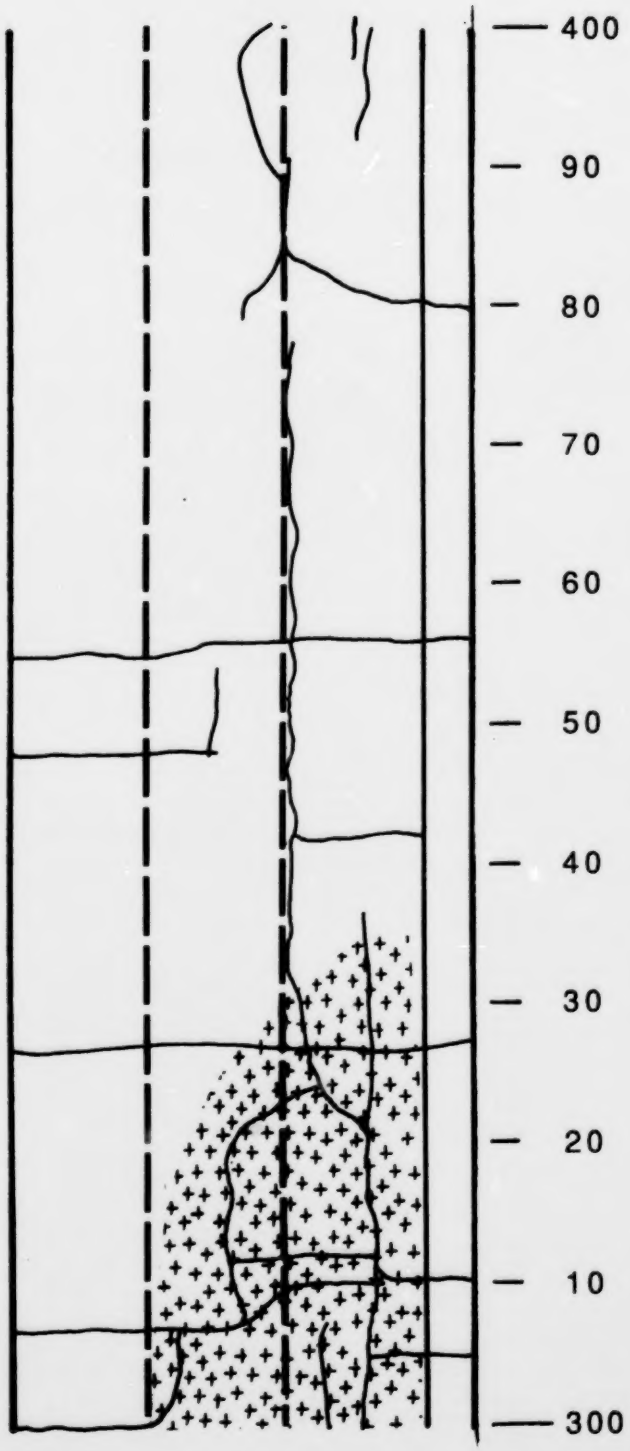
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